# Simulation of Multipactoring Effects

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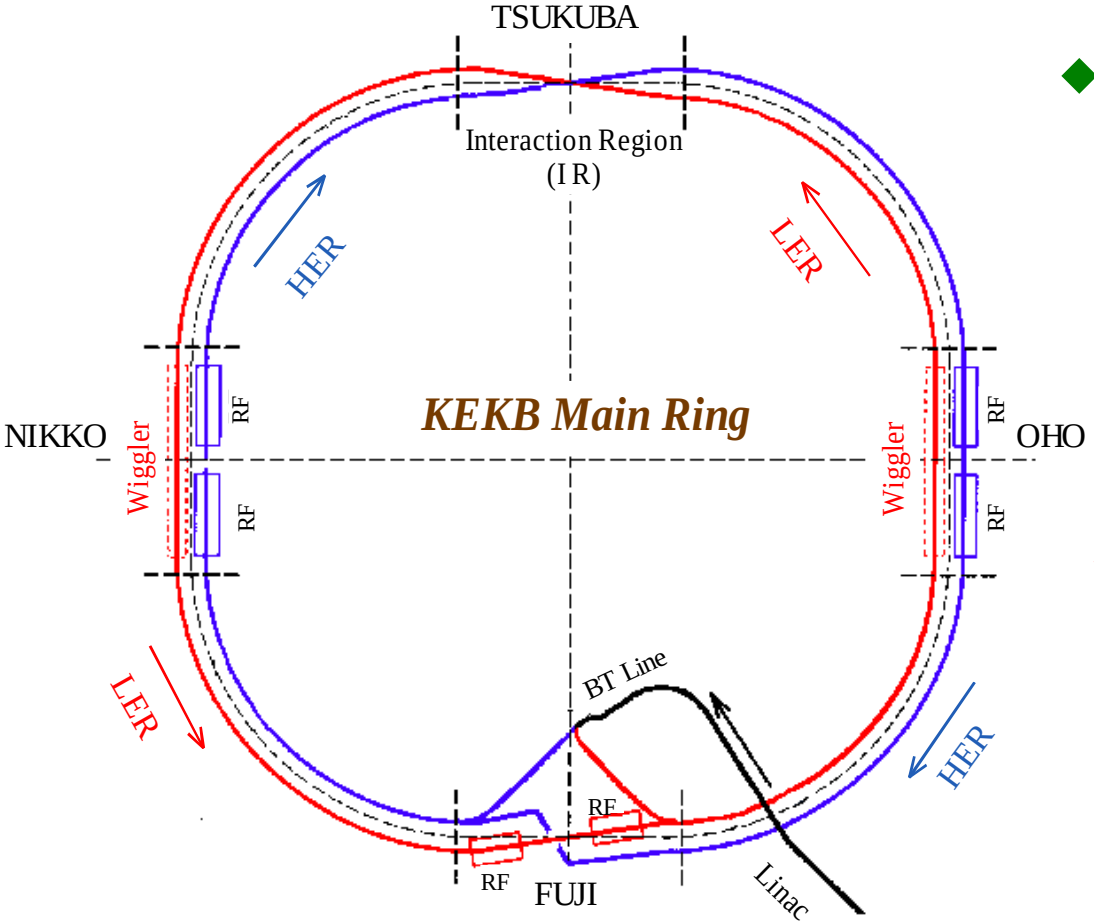
## Contents

# Introduction

## KEKB Ring

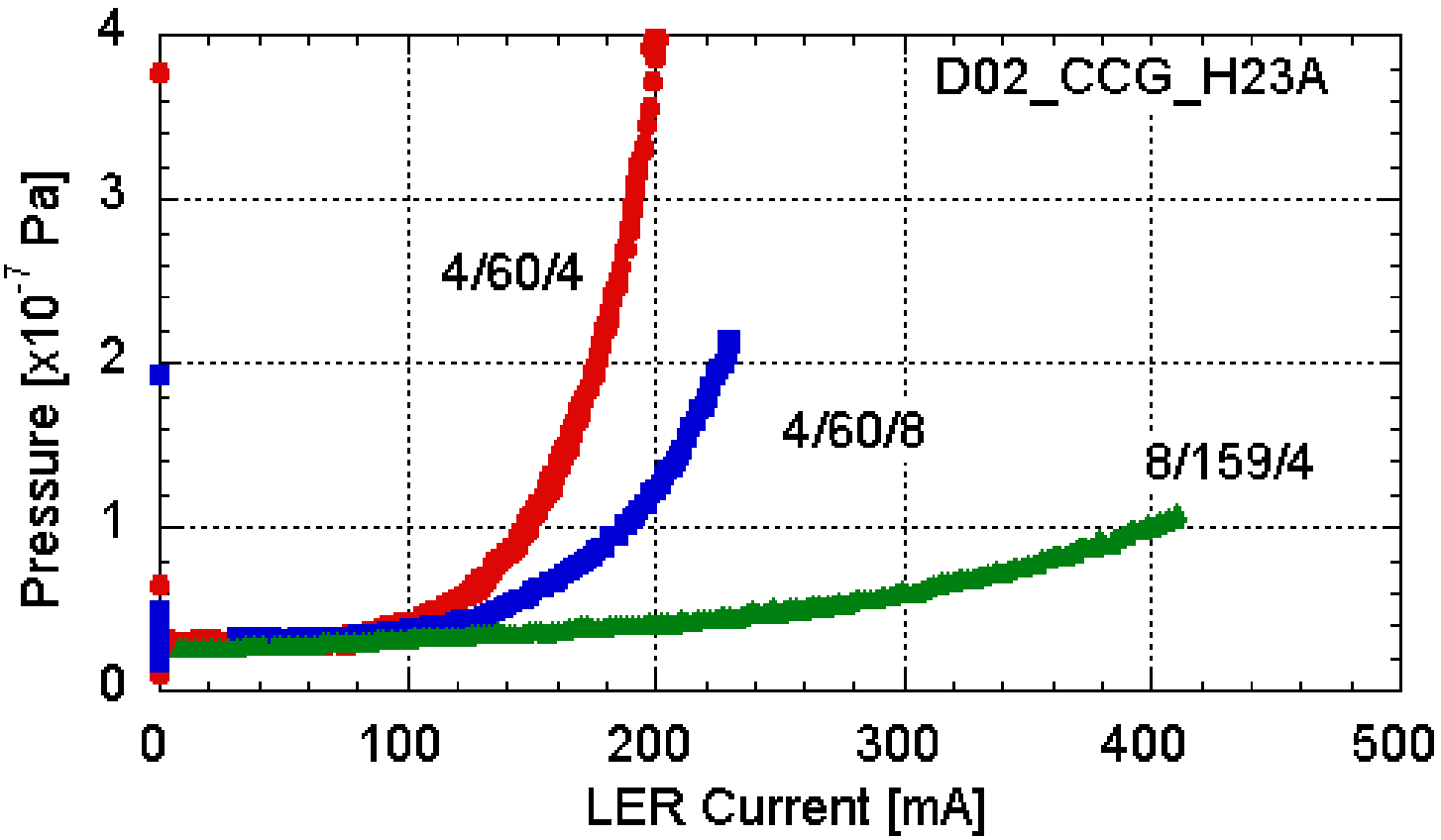



Layout of KEKB main ring.

- Positron Ring (LER)
  - Energy : 3.5 GeV
  - Current : ~1 A
- Non-linear pressure rise against the beam current has been observed.

# Example - 1

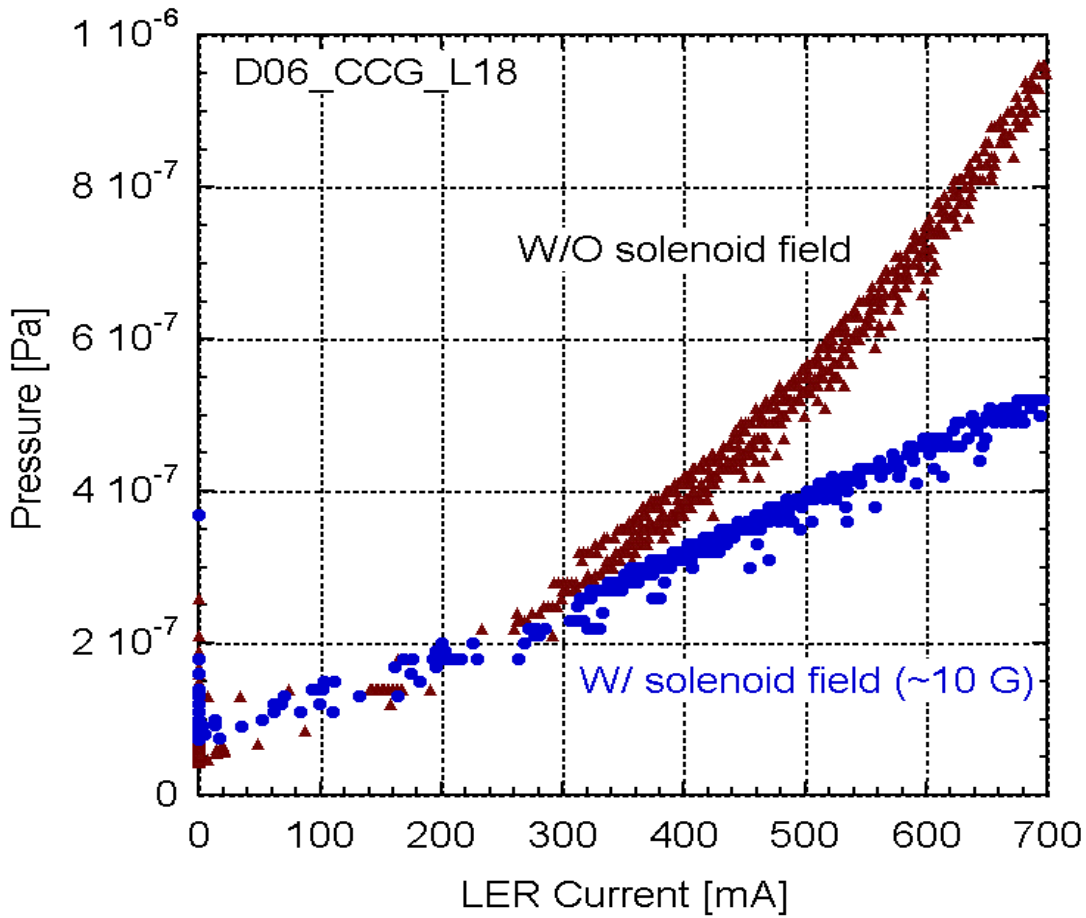
- Bunch fill pattern dependence




The symbol of 4/60/8, for an example, means that the beam consists of 4 trains of 60 bunches filled with every 8 RF buckets spacing (16 ns).

# Example - 2

- Magnetic Field Dependence




Beam current dependence of pressures for with and without solenoid field of about 10 G.

# Characteristics

(1) The pressure rise is not due to only the synchrotron radiation, where the pressure is in proportion to the beam current.

(2) The different bunch patterns and the bunch currents give the different behaviors of pressure rise.

(3) The non-linearity is strong at the place without magnetic field (the straight section). The non-linearity reduces by applying a solenoid magnetic field of several gausses.

(4) The pressure increases rapidly at some beam current.

⟹ Gas desorption due to the electron multipactoring.

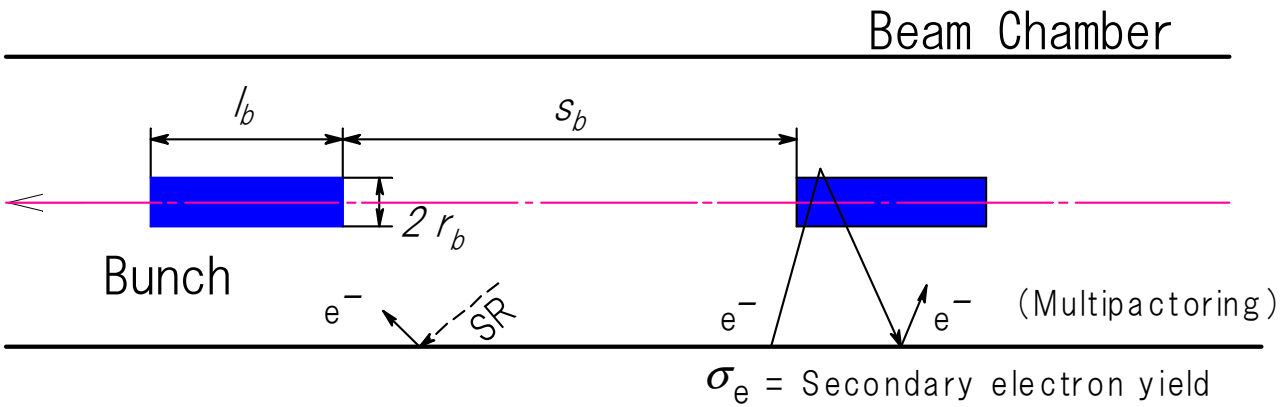
# Purpose

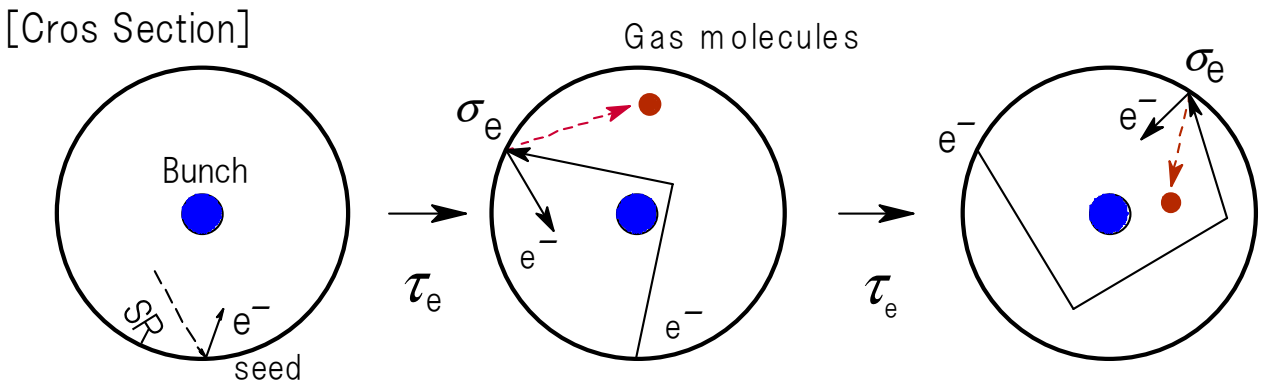
- Propose a simple simulation method assuming that the non-linear pressure rise is due to the multipactoring of the electrons.

  Based idea was given by O.Gröbner (CERN,1977)
- Give some information on the beam size blow up issues.

  (The behavior is similar to that of the blow up of the vertical beam size as shown later)

# Simulation Model

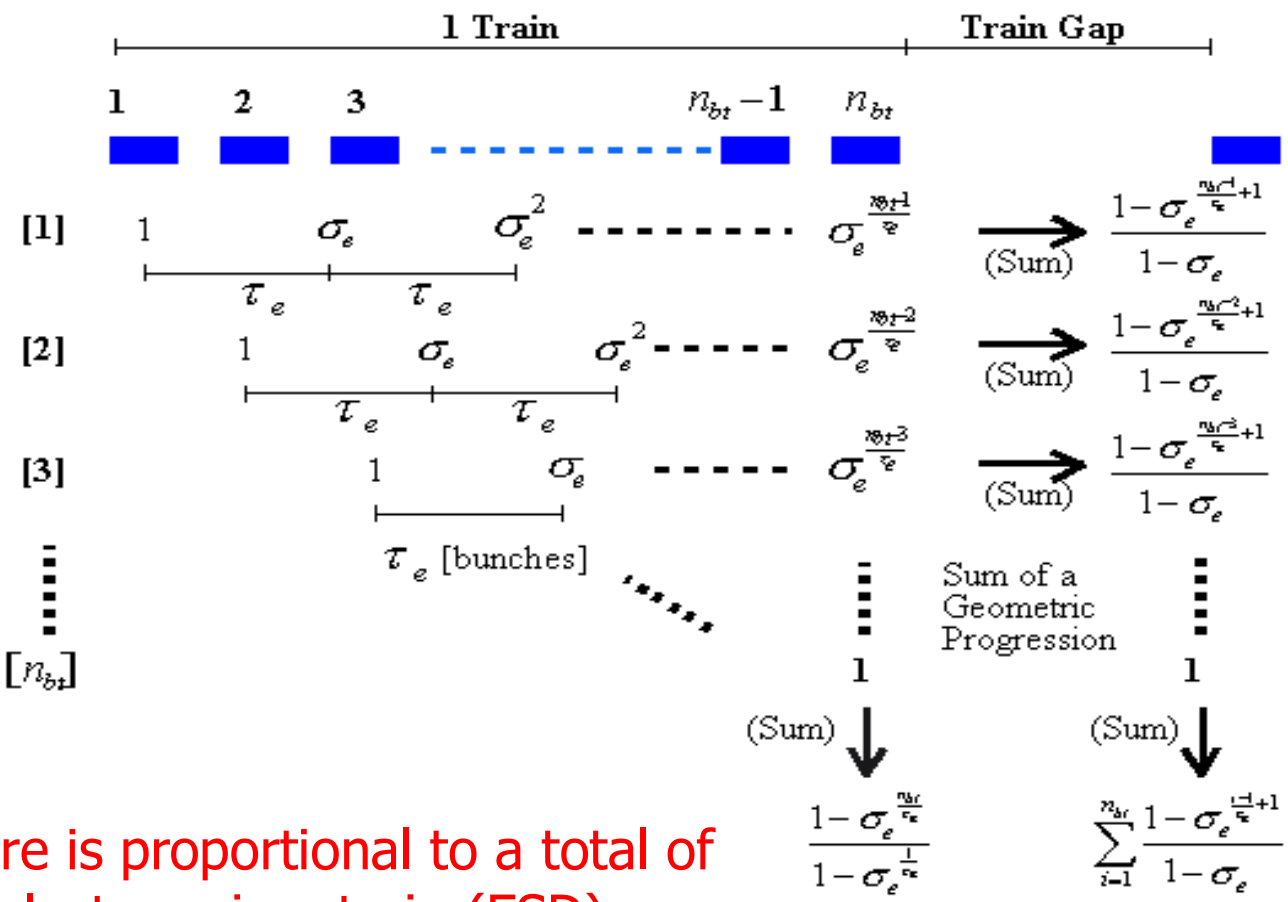



Electron emission
→ Acceleration by $e^+$ bunches
→ Bombardment to wall with a high energy
→ Secondary electron emission

Here, calculate average $\sigma_e$ and $\tau_e$ for many electrons.

# Calculation Method




The pressure is proportional to a total of generated electrons in a train (ESD).

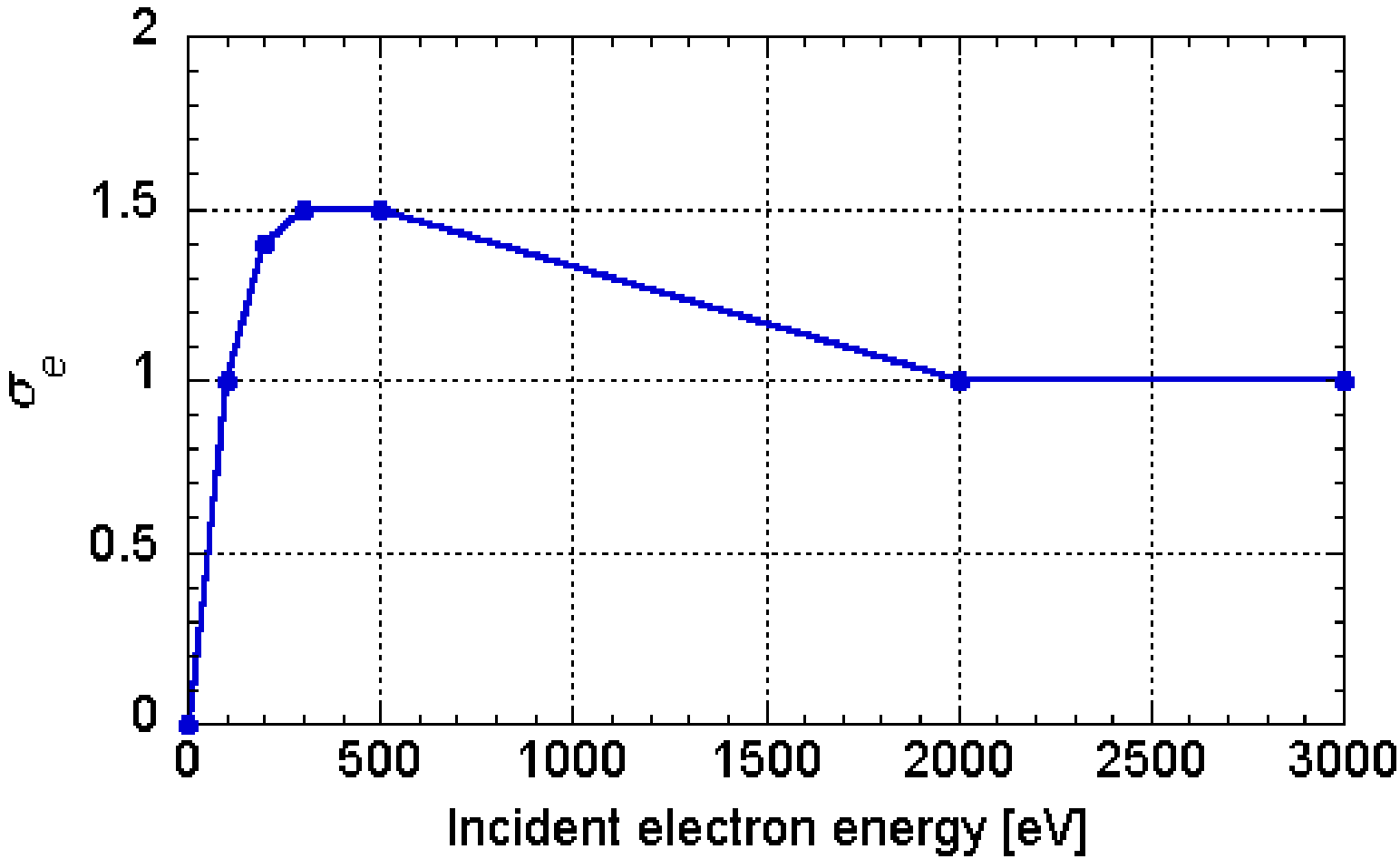
$$P \propto I_{bunch} \times N_{train} \times \sum_{i=1}^{n_{bt}} \frac{1-\sigma_e^{\frac{i-1}{\tau_e}-1}}{1-\sigma_e}$$

$I_{bunch}$ : bunch current
$N_{train}$ : number of train
$n_{bt}$ : bunch number in a train

# Assumptions

- Initial energy of emitted electrons is in the range 2 ~ 8 eV.
- $r_b$ = 200 μm, $l_b$ = 20 mm (about 3 $\sigma_z$), and $s_b$ = 4 – 12 RF buckets (1 bucket = 2 ns). Similar results were obtained for Gaussian beam.
- No axial motion (two dimensions).
- ESD coefficient, i.e., the number of gas molecules emitted for one electron, is constant.
- Chamber is a circular pipe.
- Emitted electrons follows the cosine law.
- Tracking starts at a random time between adjoining bunches.
- Electrons and gas molecules inside the chamber is completely cleared during a train gap.
- A simplified typical secondary electron yield is used.

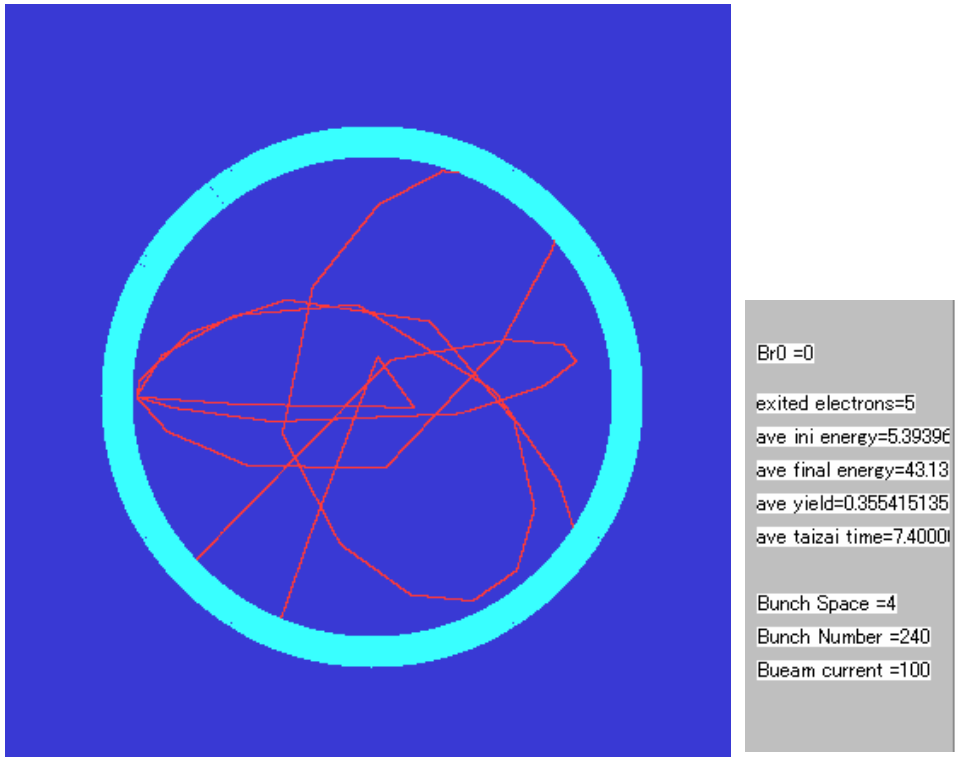
# Assumed $\sigma_e$ (secondary electron yield):




Assumed energy dependence of the secondary yield, $\sigma_e$, for copper surface.

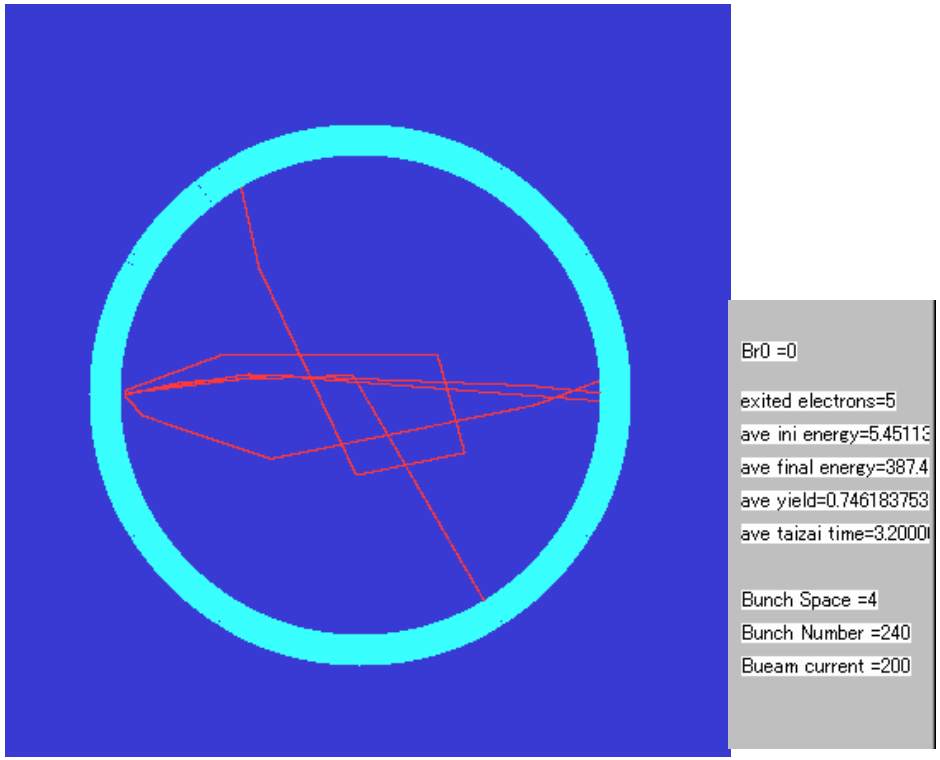
# Example of Trajectory - 1

- No Magnetic Field




4/60/4

100 mA

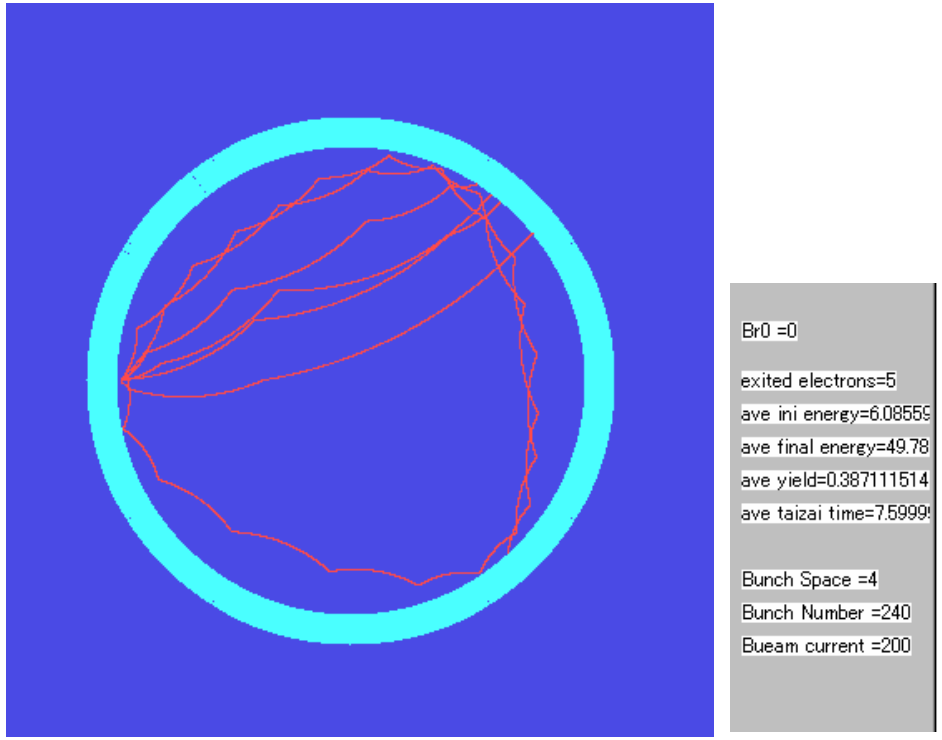



4/60/4

200 mA

# Example of Trajectory - 2

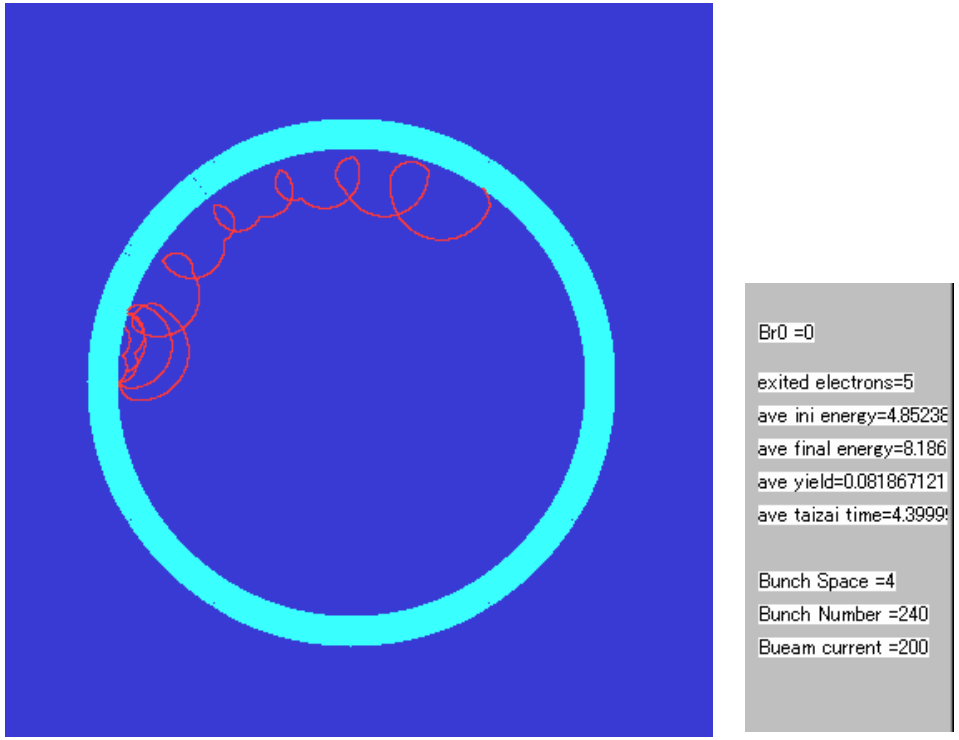
- With Solenoid Field




4/60/4

200 mA

Bz = 5 G



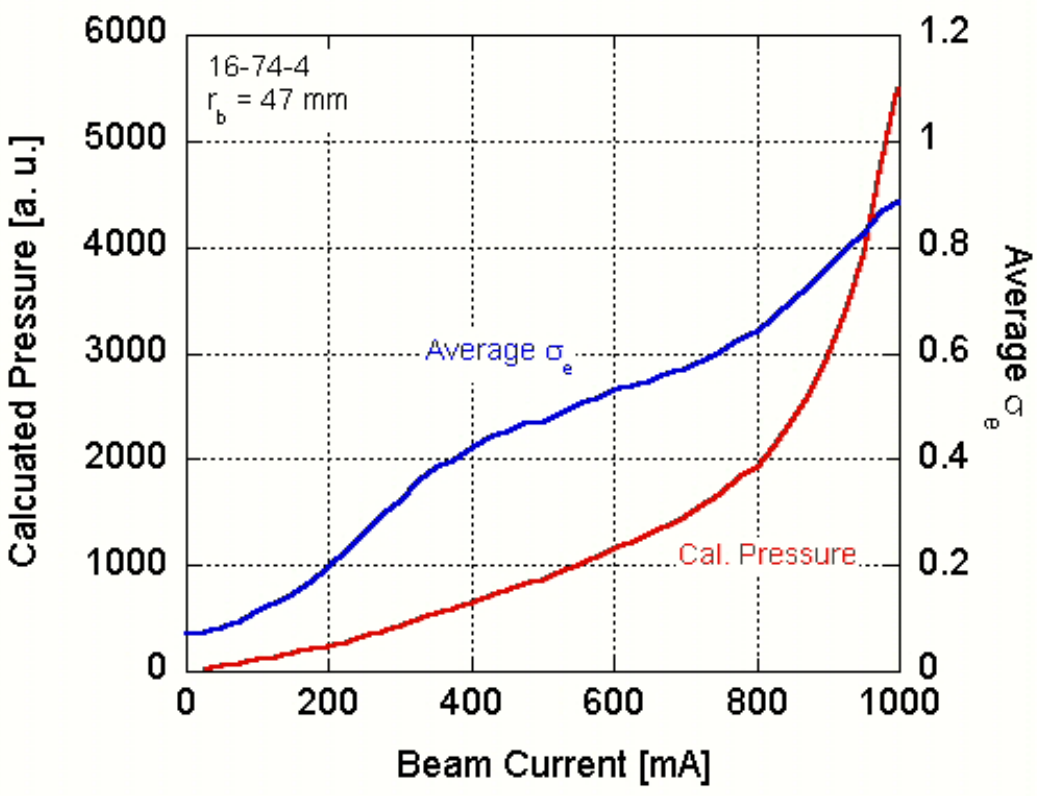

4/60/4

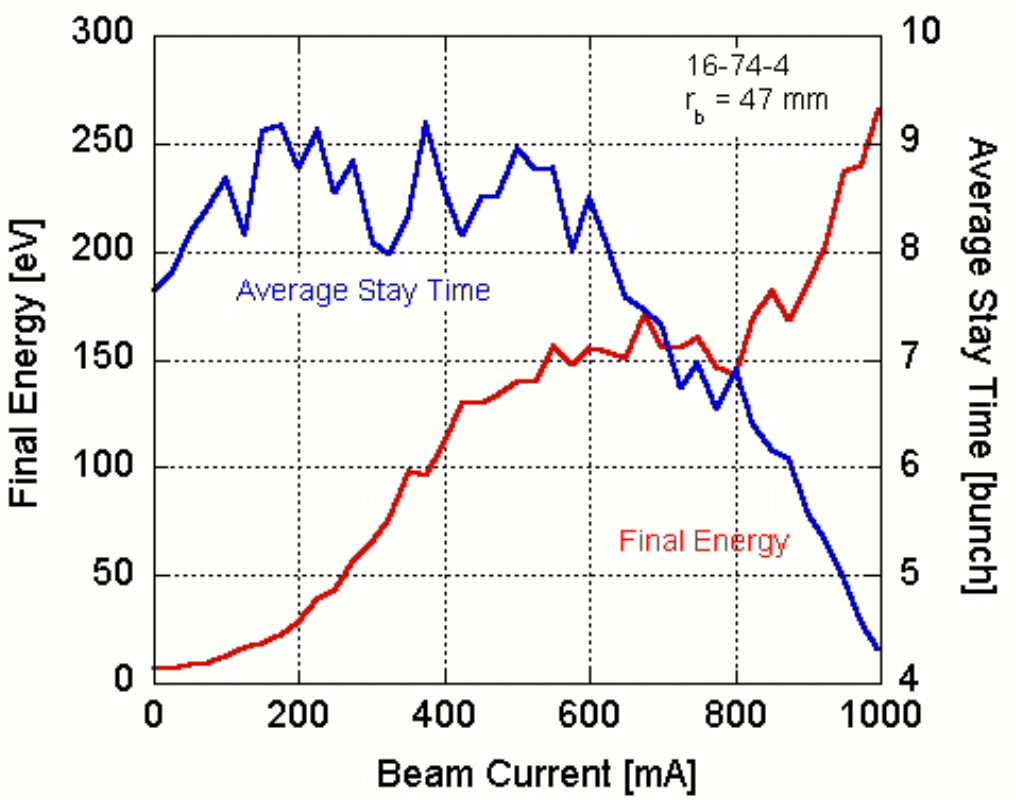
200 mA

Bz = 20 G

# Result - 0

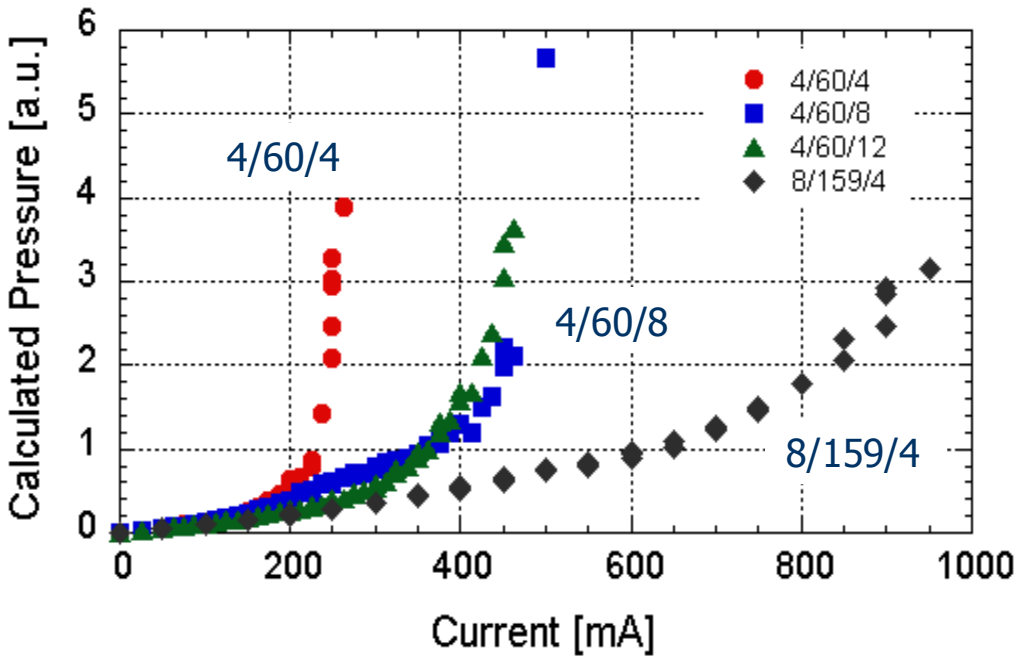
- Typical Result

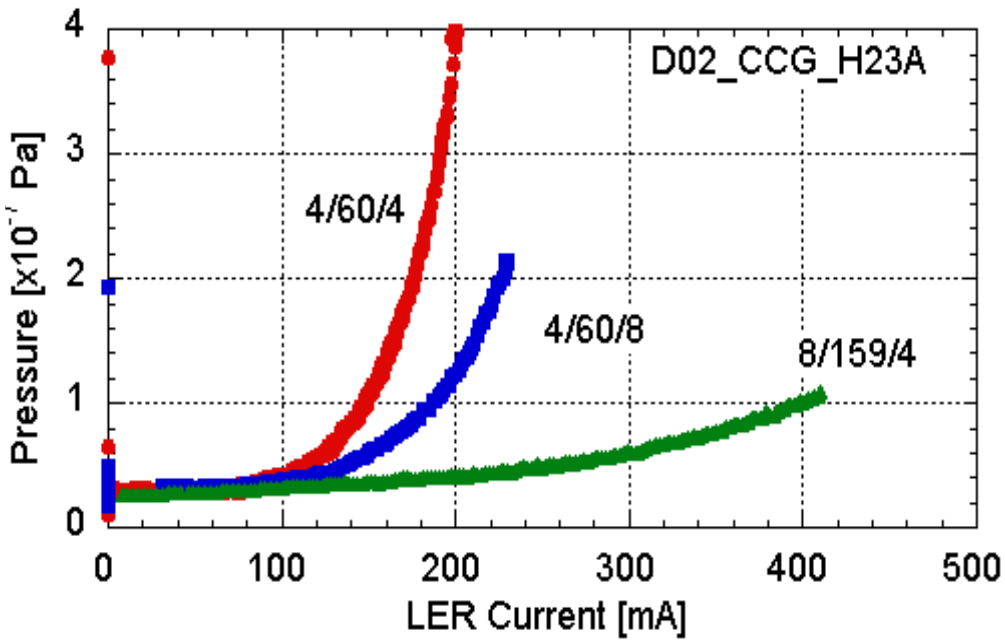


# Result - 1

- Bunch Fill Pattern Dependence

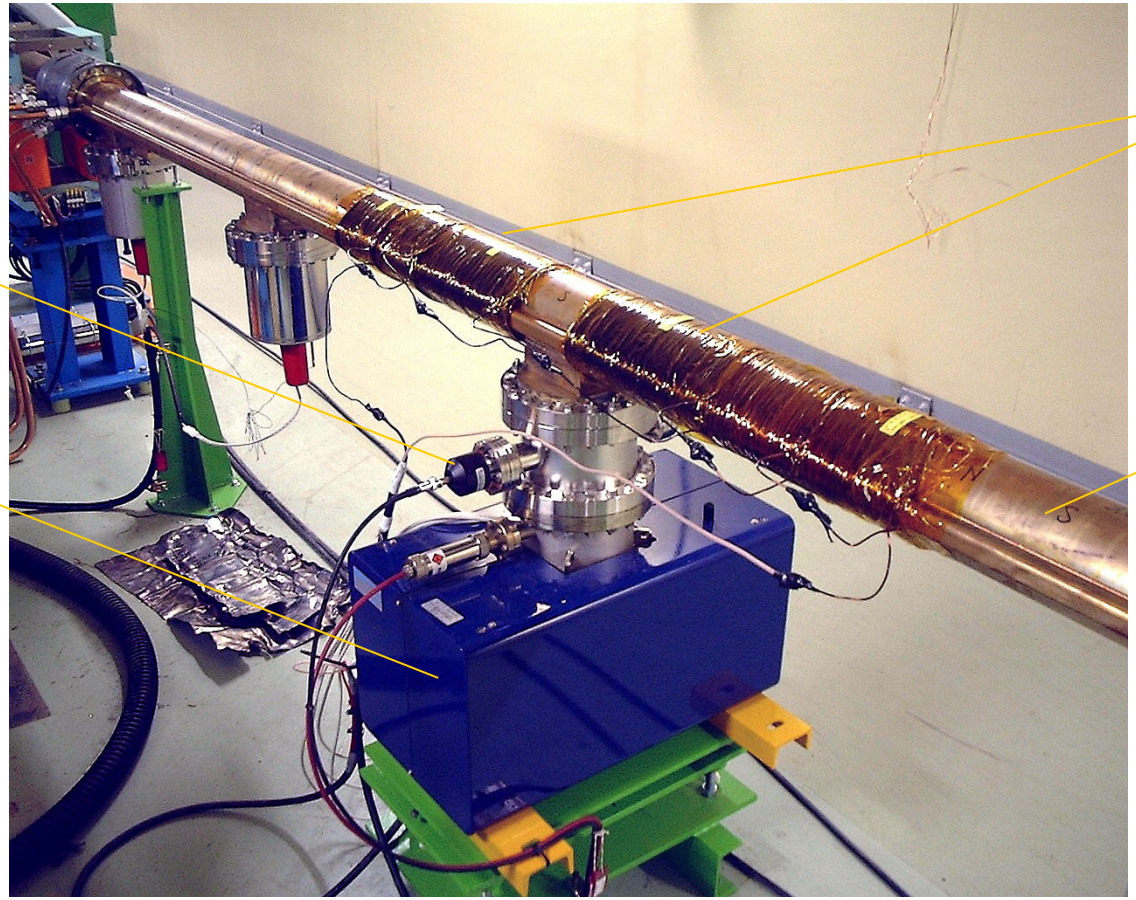



The behavior is very similar to observation although the corresponding current is somewhat different.

# Solenoid (Local)

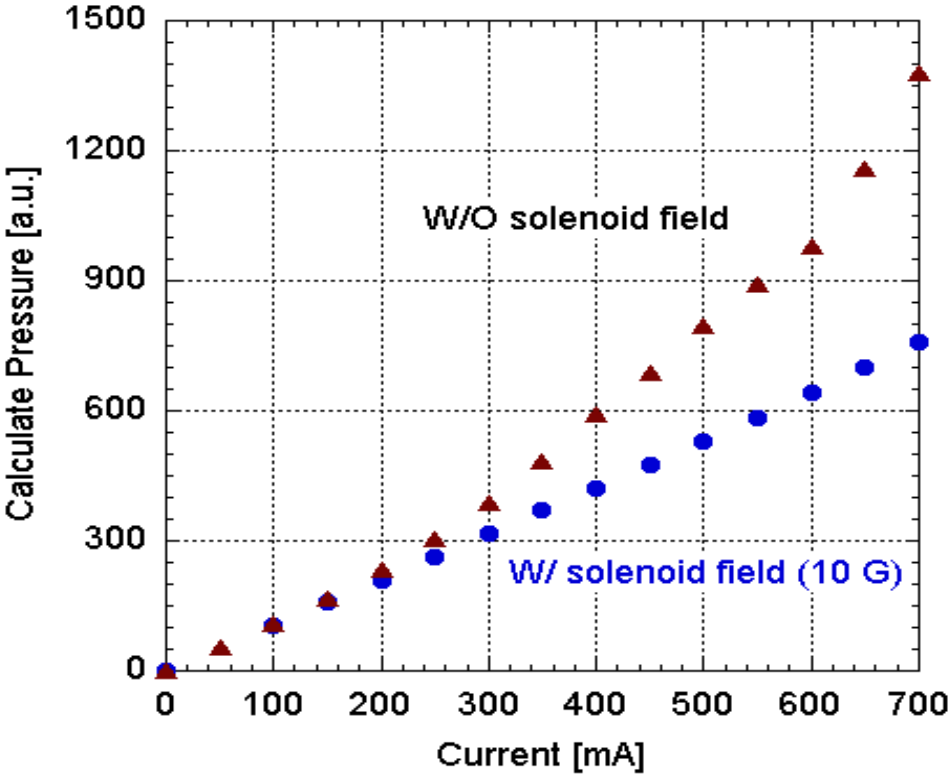
- Solenoid around Gauge

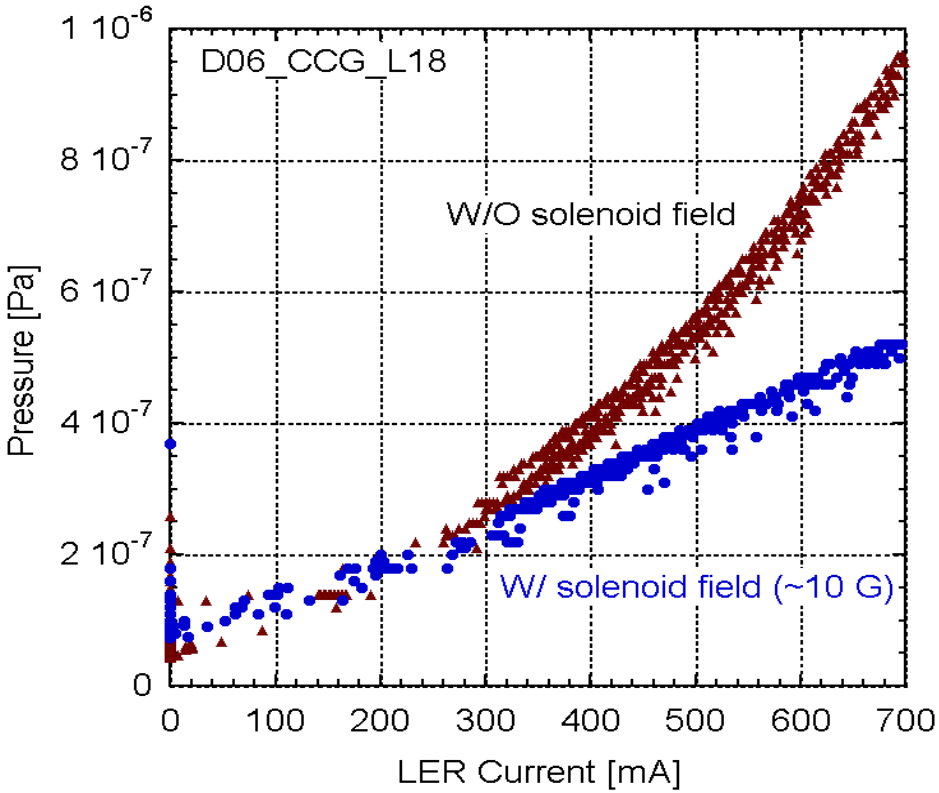



Solenoids winded around the LER chamber above a CCG.

# Result - 2

- Magnetic Field Dependence

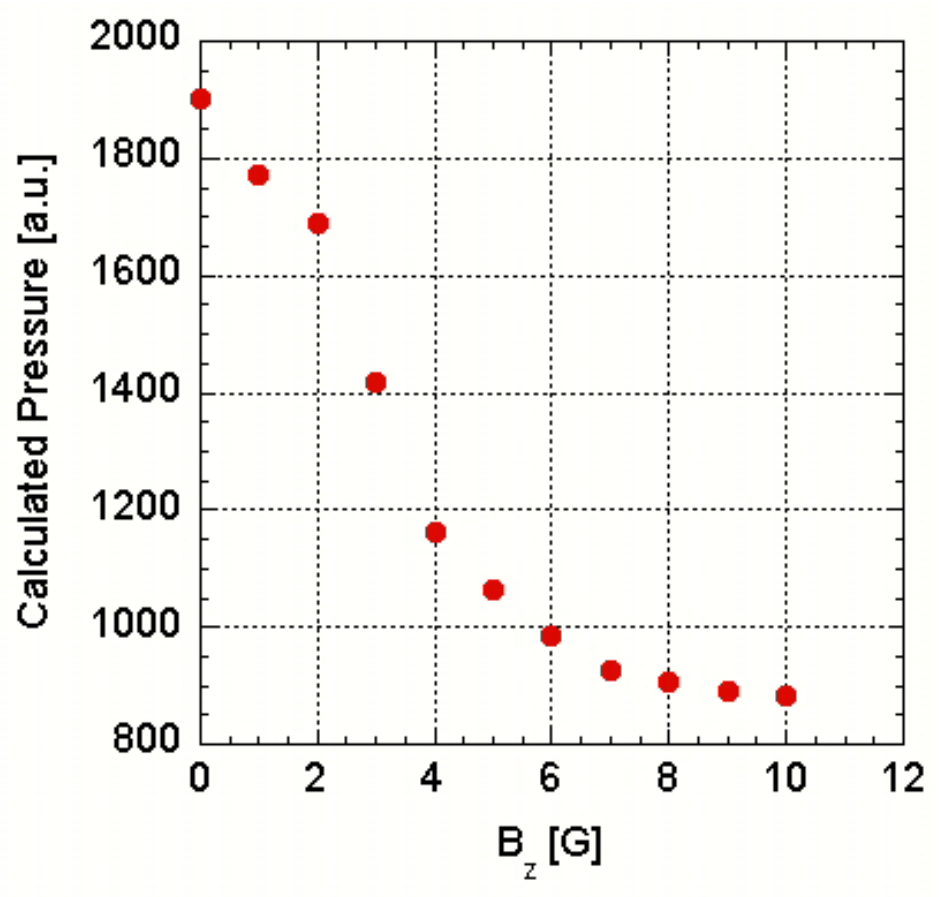


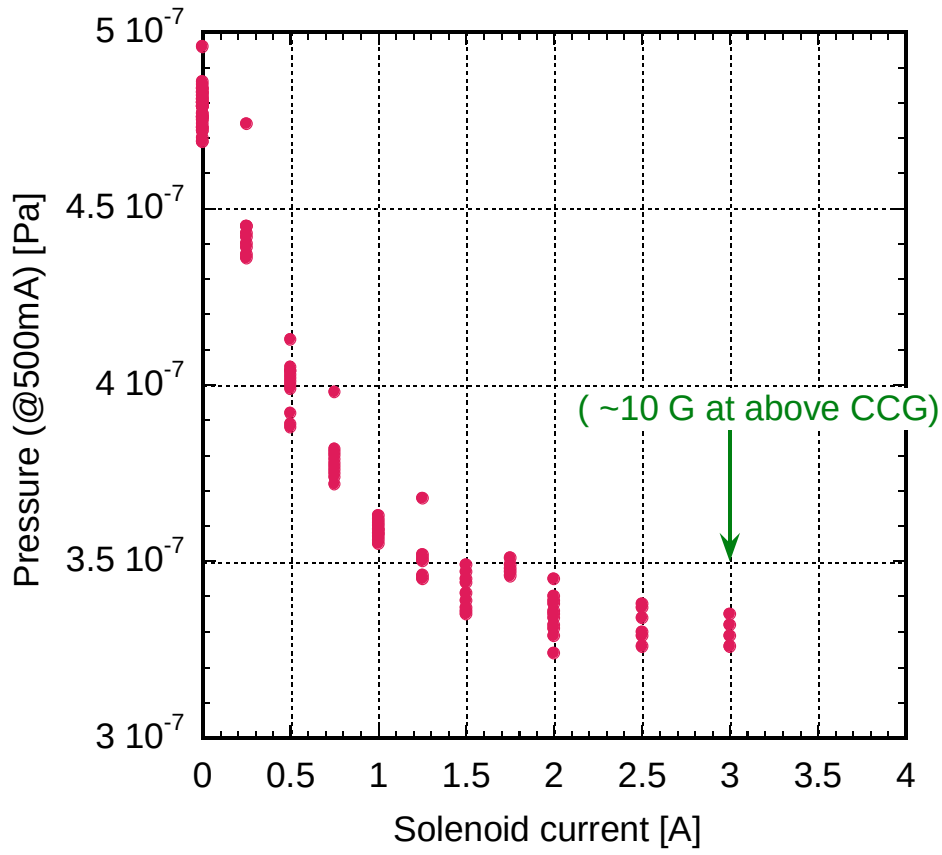




Solenoid field about 10 G reduce the non-linear behavior.

# Result - 3

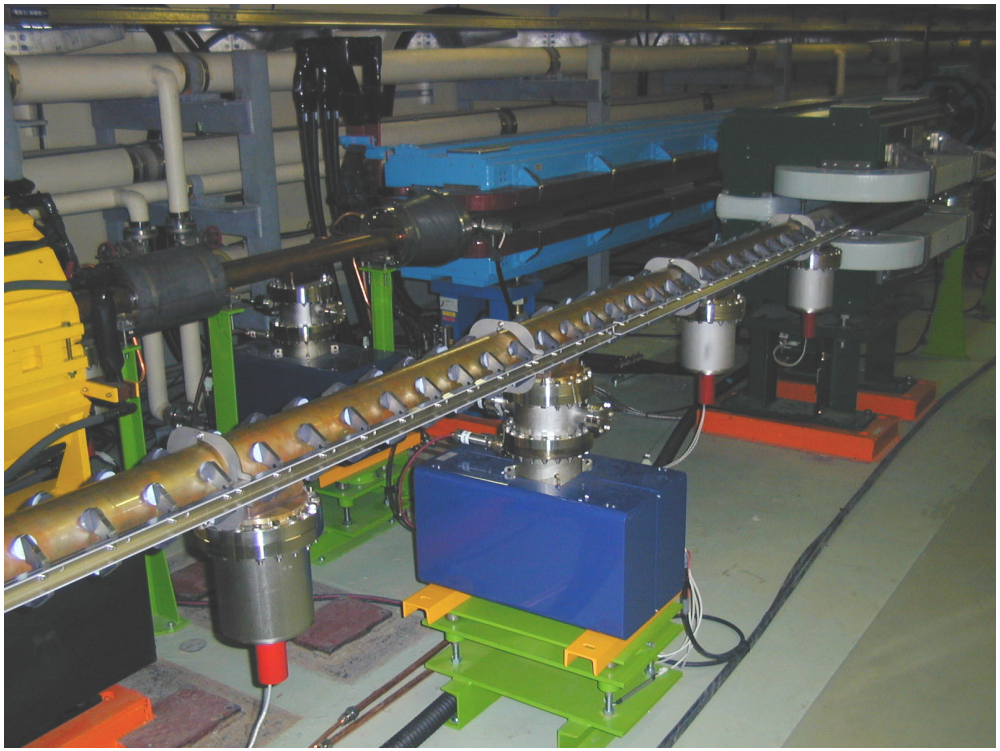
- Dependence on Magnetic Field Strength

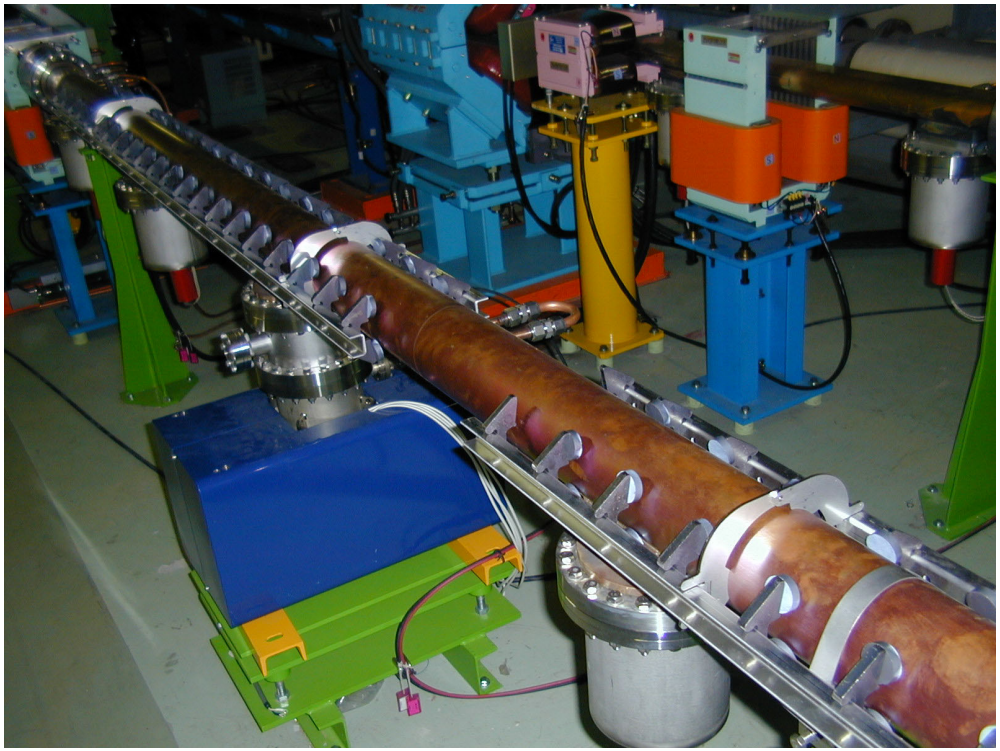



Observed (left) and calculated (right) change of the pressures against the solenoid field strength.

# C-yoke (Permanent Magnets)

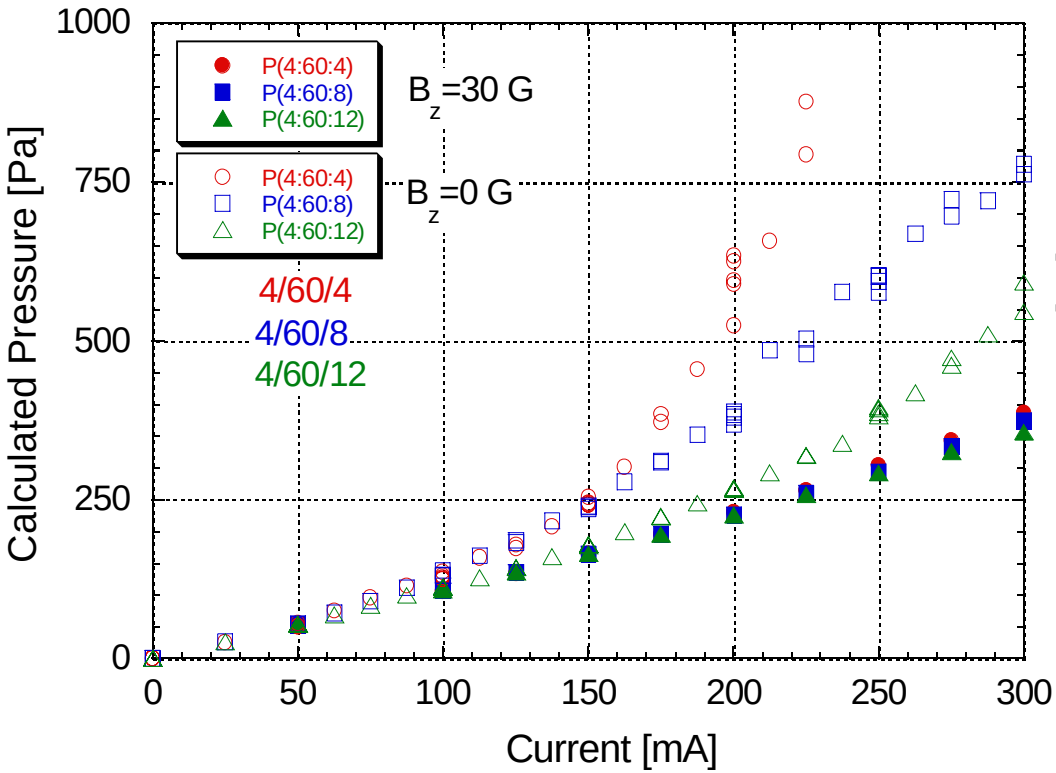


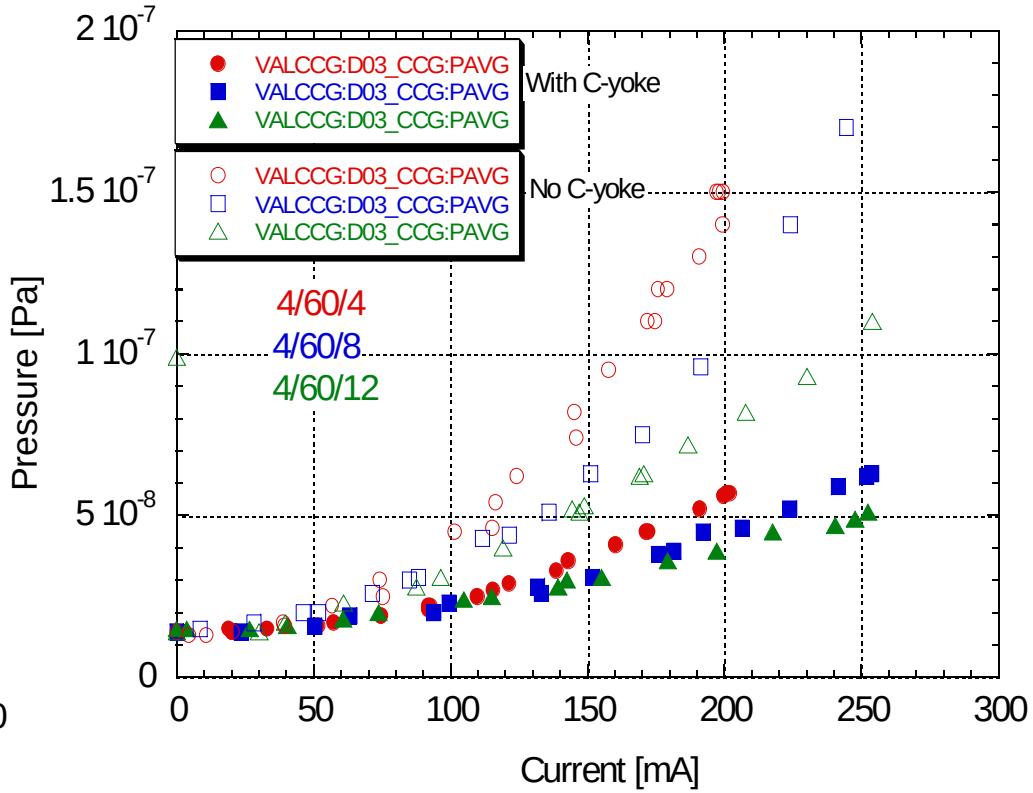


C-yoke type permanent magnets ($\phi$30) around the beam chamber (until last summer).

# Result - 4

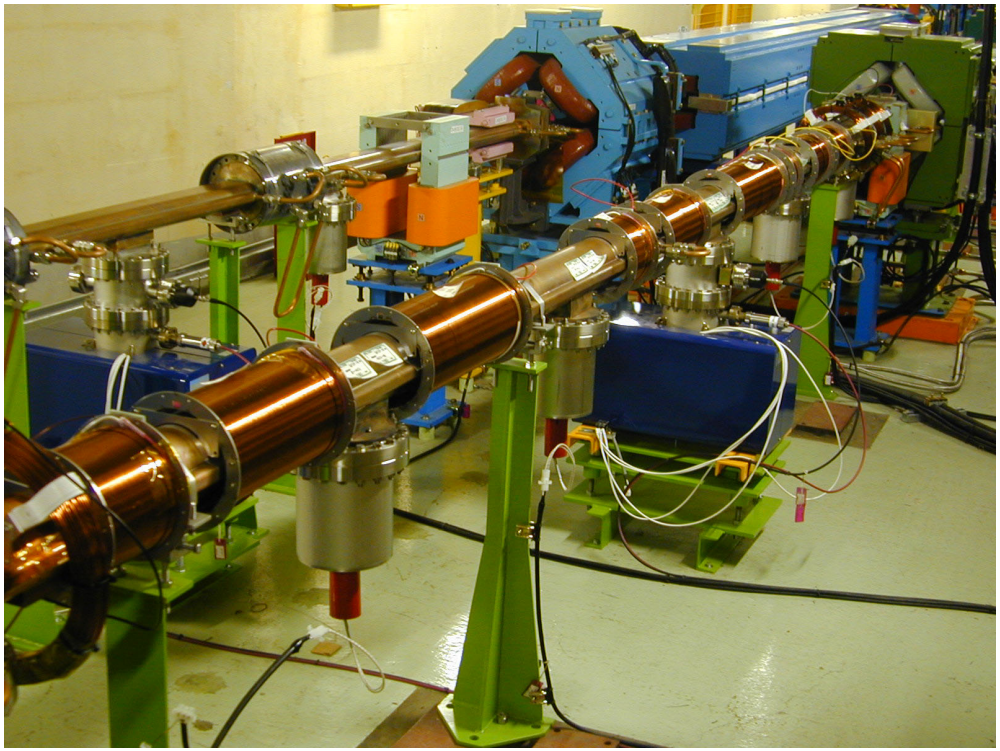
- Effect of C-yoke

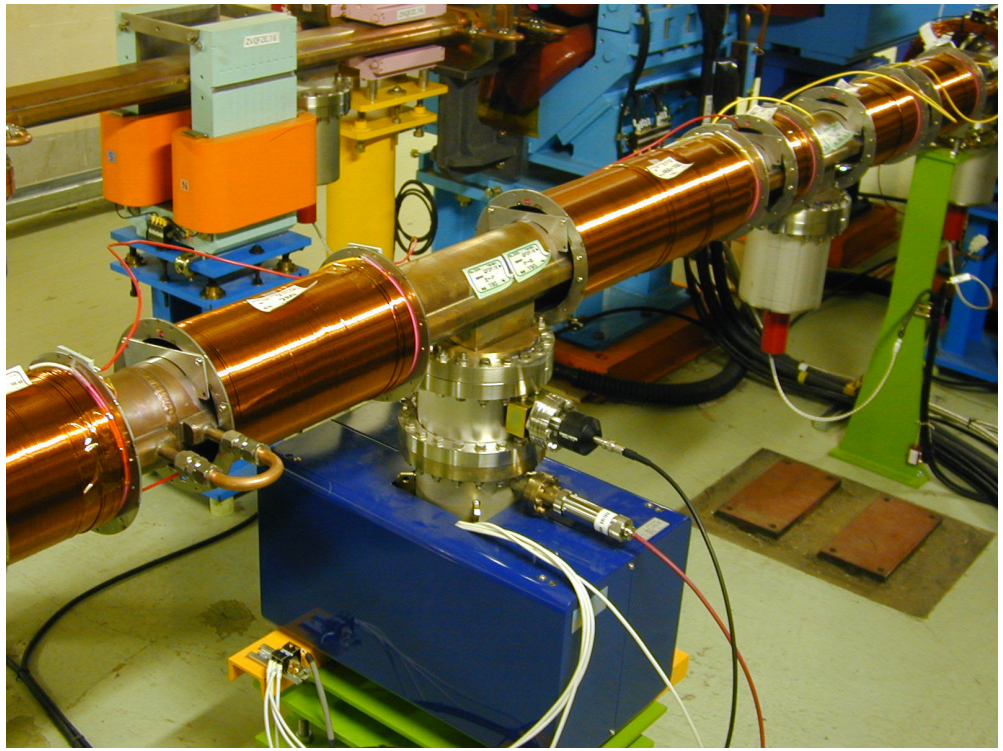



For simplicity, the calculation was performed for solenoid field.

# Solenoid (whole ring)

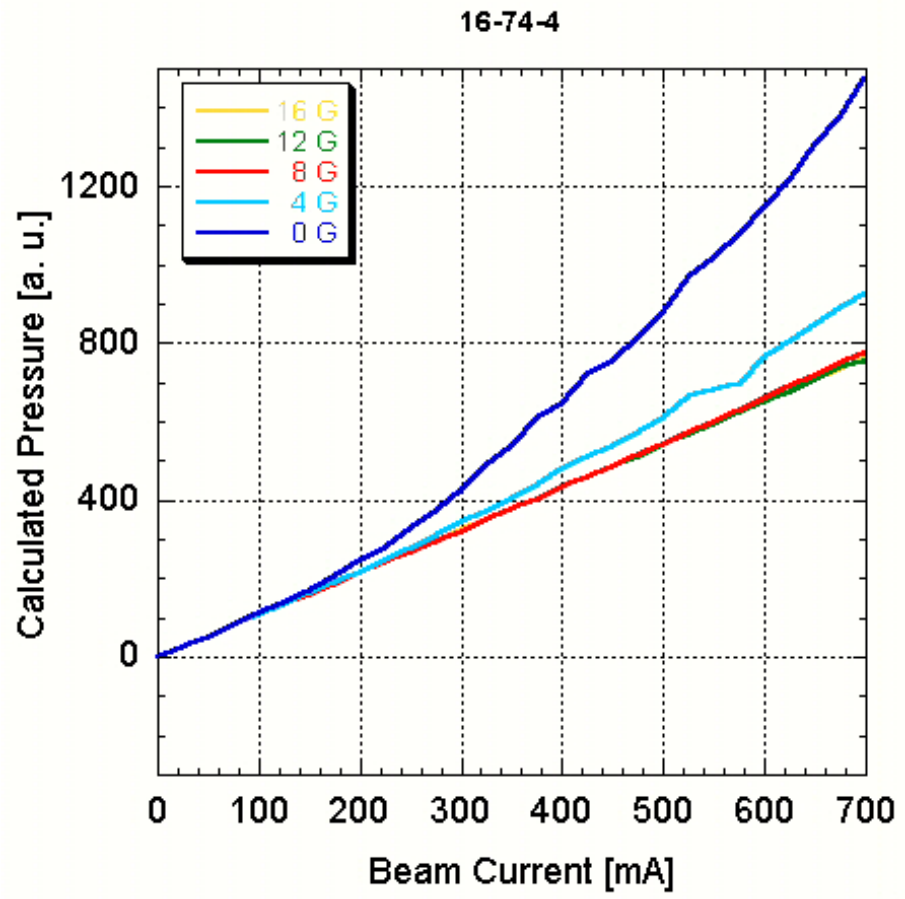


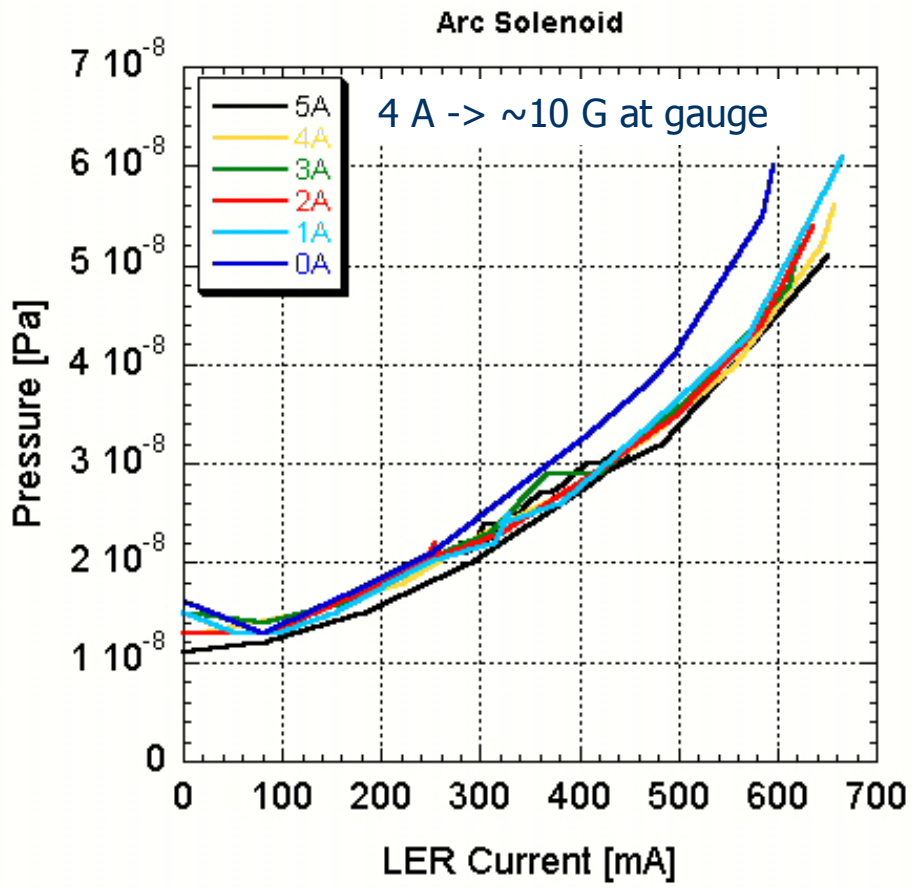


Last summer solenoids were winded mainly at arc sections.

# Result - 5

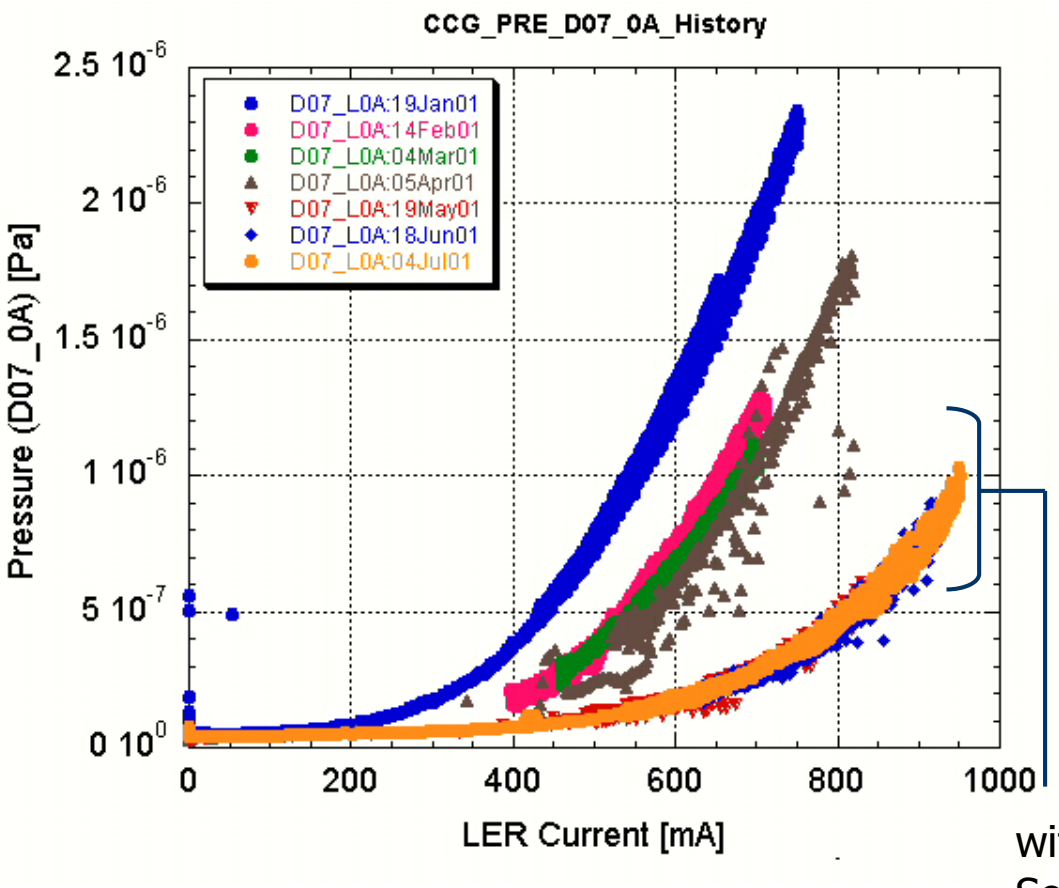
- Effect of Solenoid



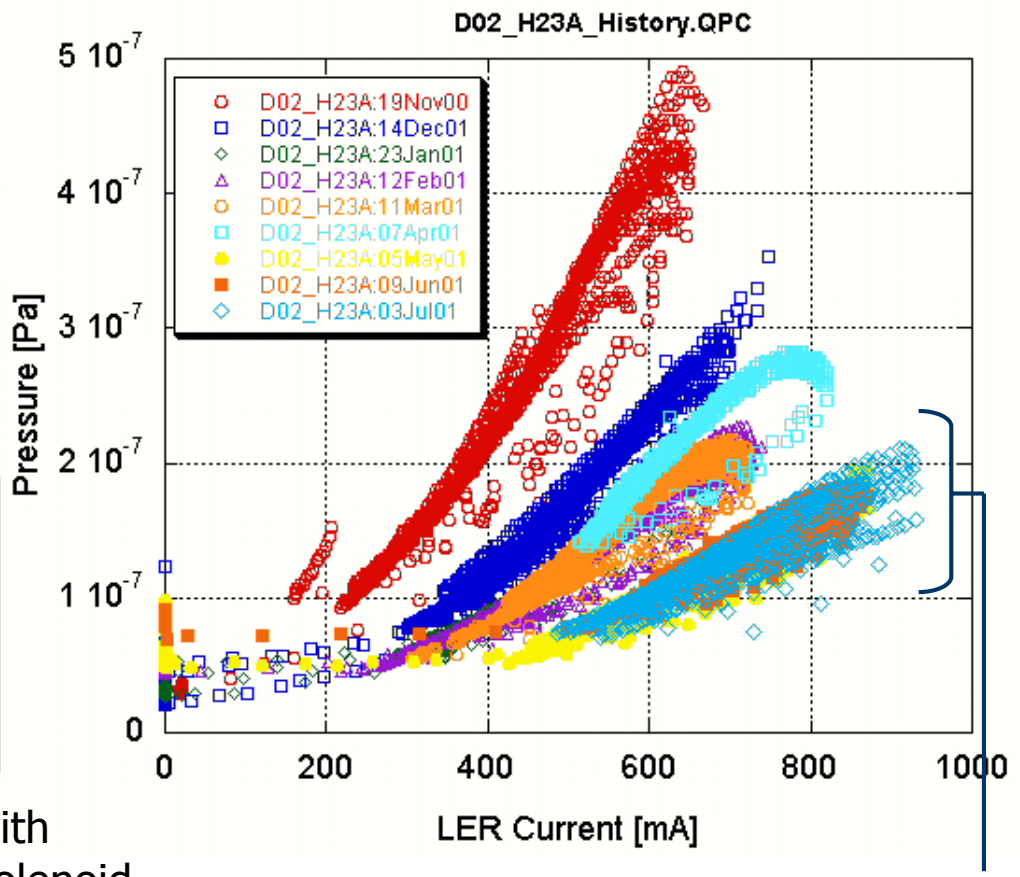




The difference for field strength is not so clear. The tendency that the pressure does not change for the field larger than several G is same.

# Aging behavior (Observation)



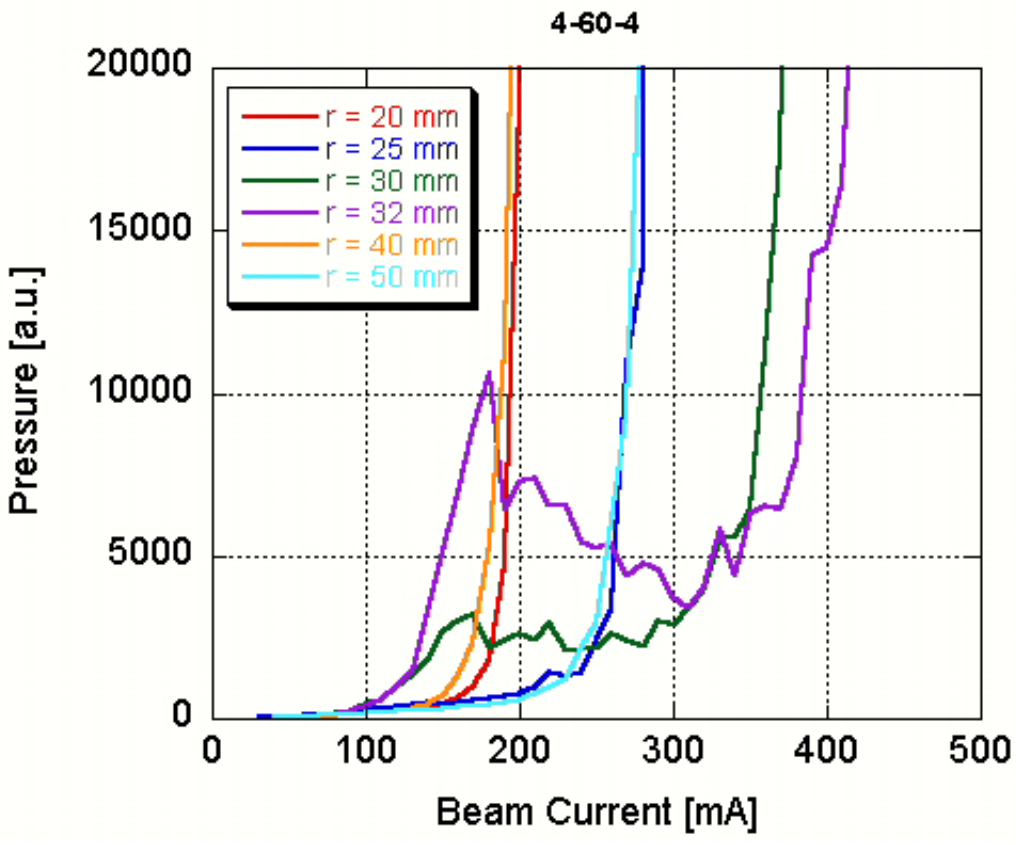

with Solenoid

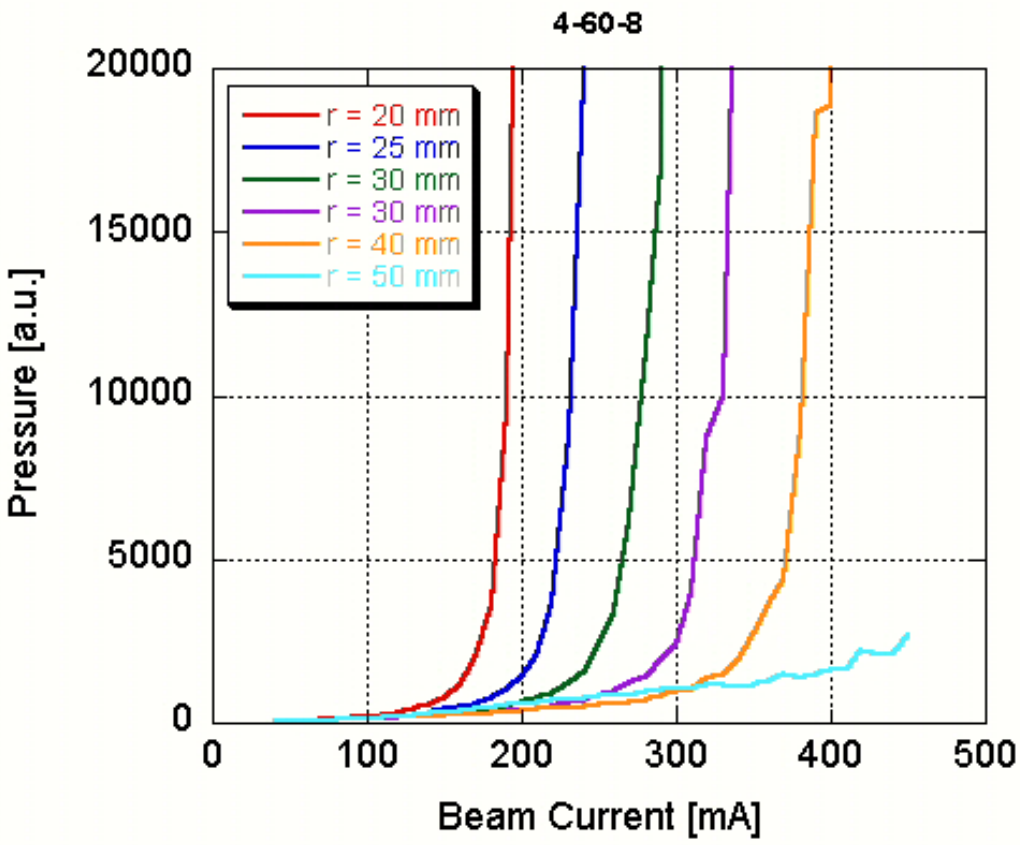



with Solenoid

The aging behavior can be explained by that of $\sigma_e$ and ESD coefficient.

# Resonance Behavior

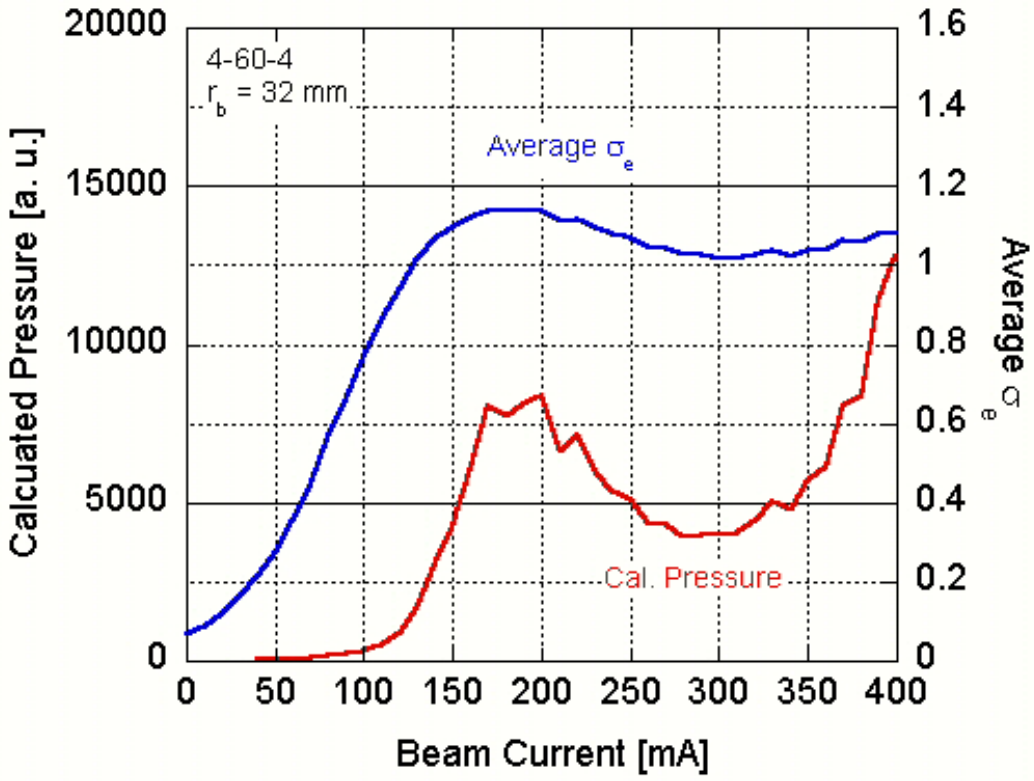


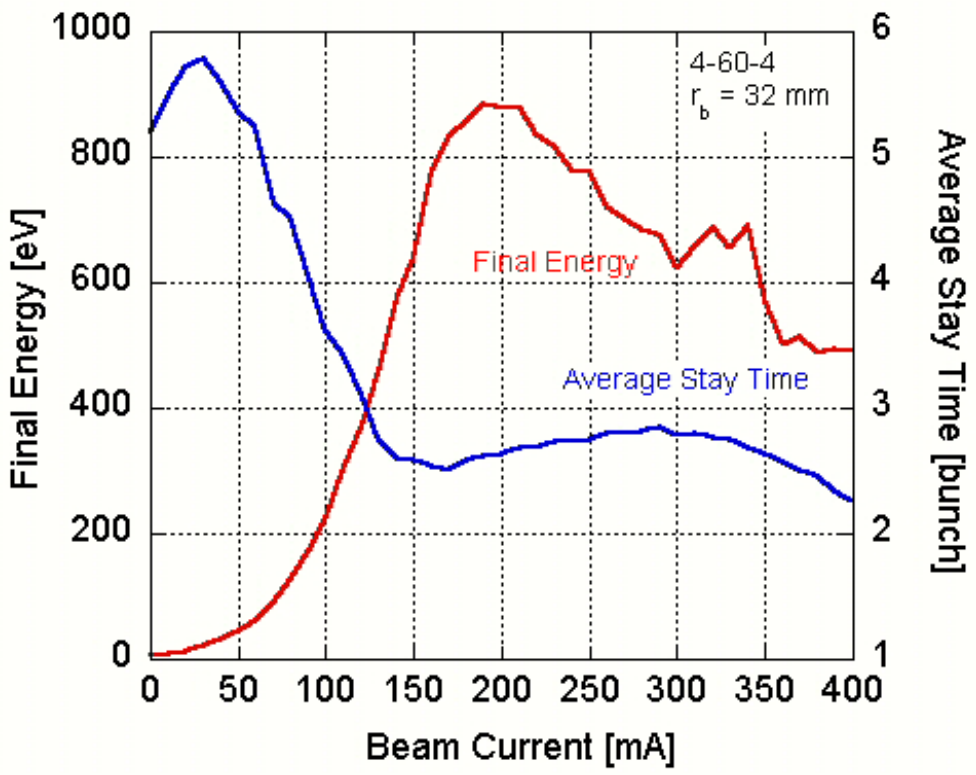




A resonance seems to occur at a particular combination of fill pattern and chamber radius etc. The resonance was not observed in KEKB.

# Resonance Behavior

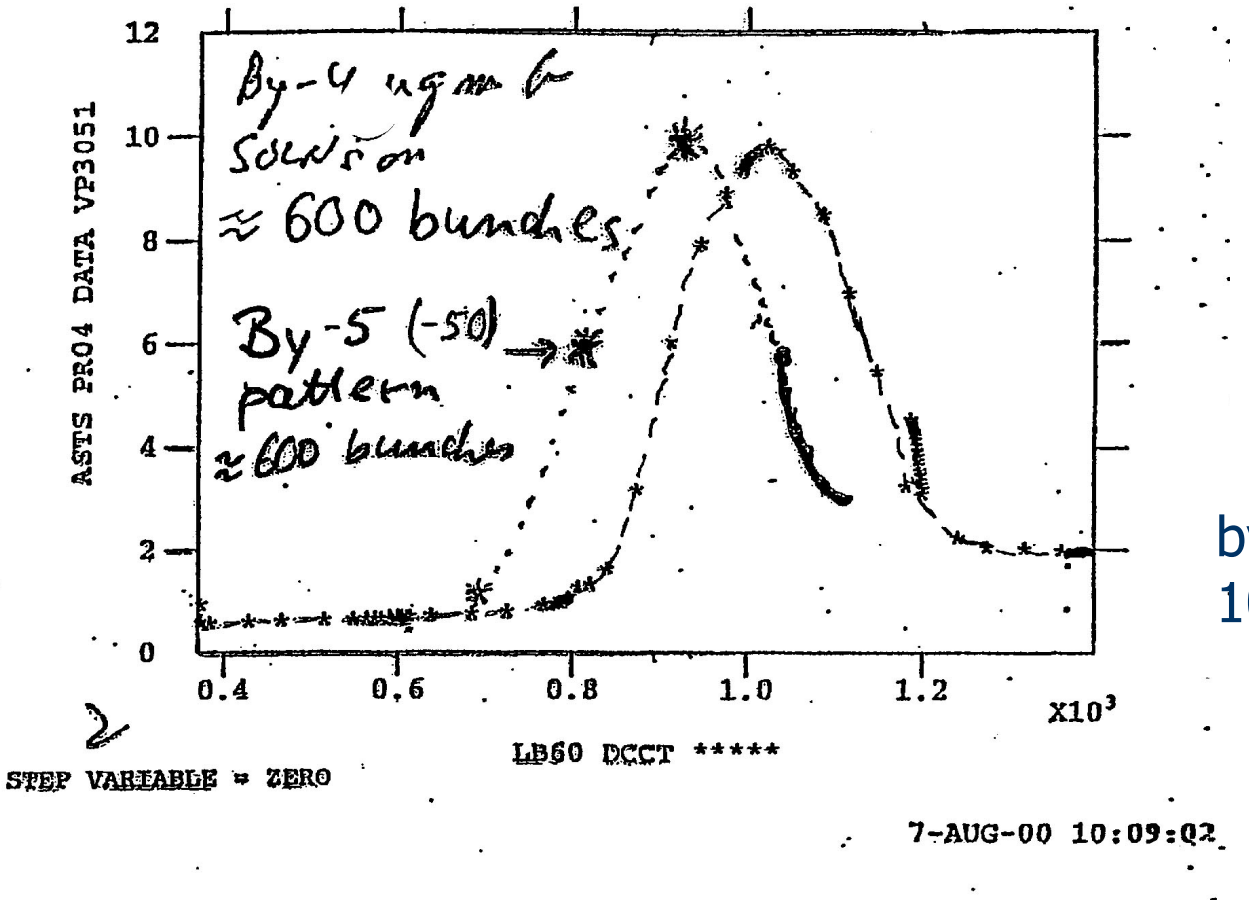
- Calculation



# Resonance Behavior

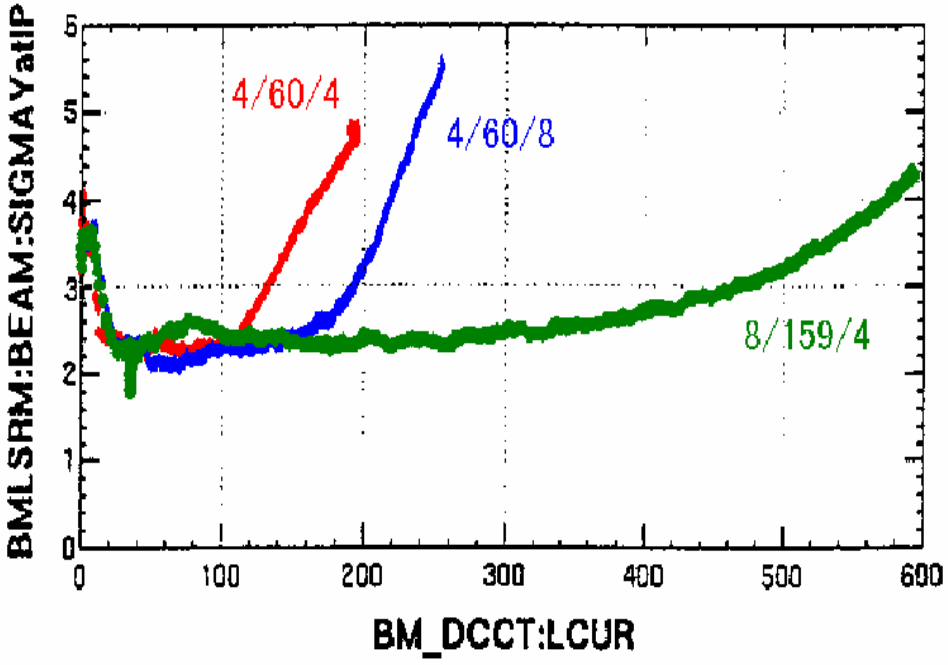
- Example at SLAC LER

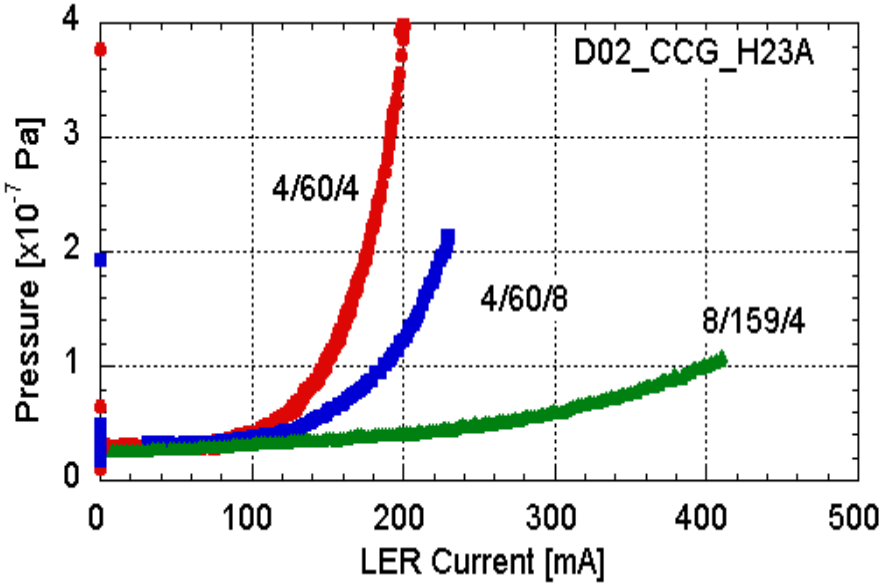


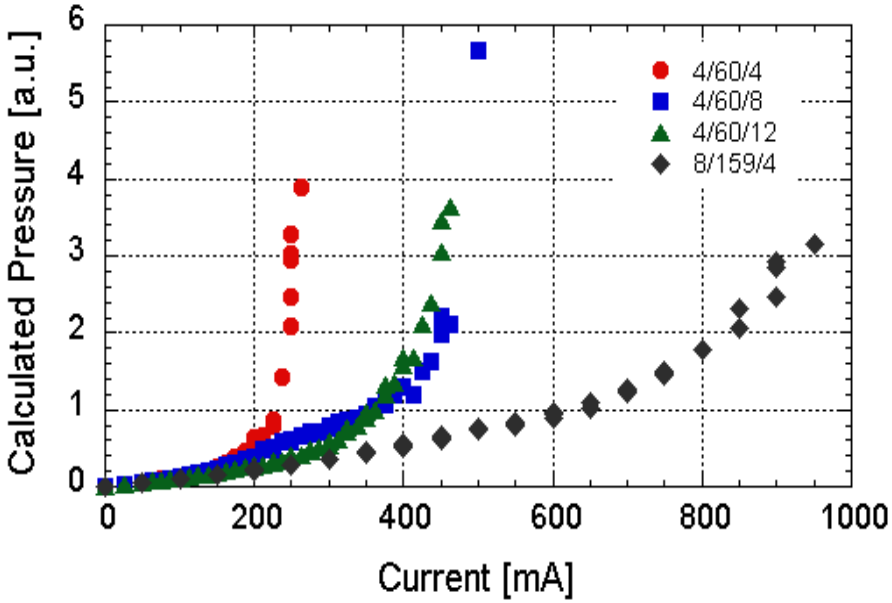

by F.-J. Decker
10-/Aug/2000

# Relation to Beam Size Blow Up

- Blow up of Vertical Beam Size



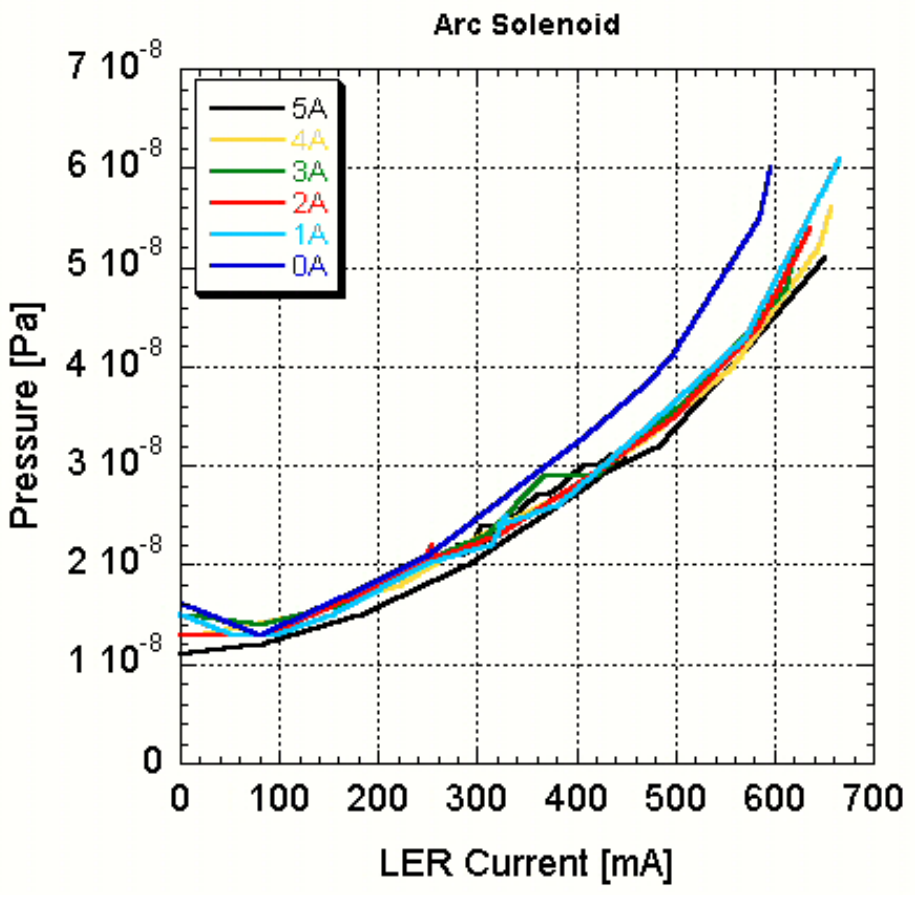



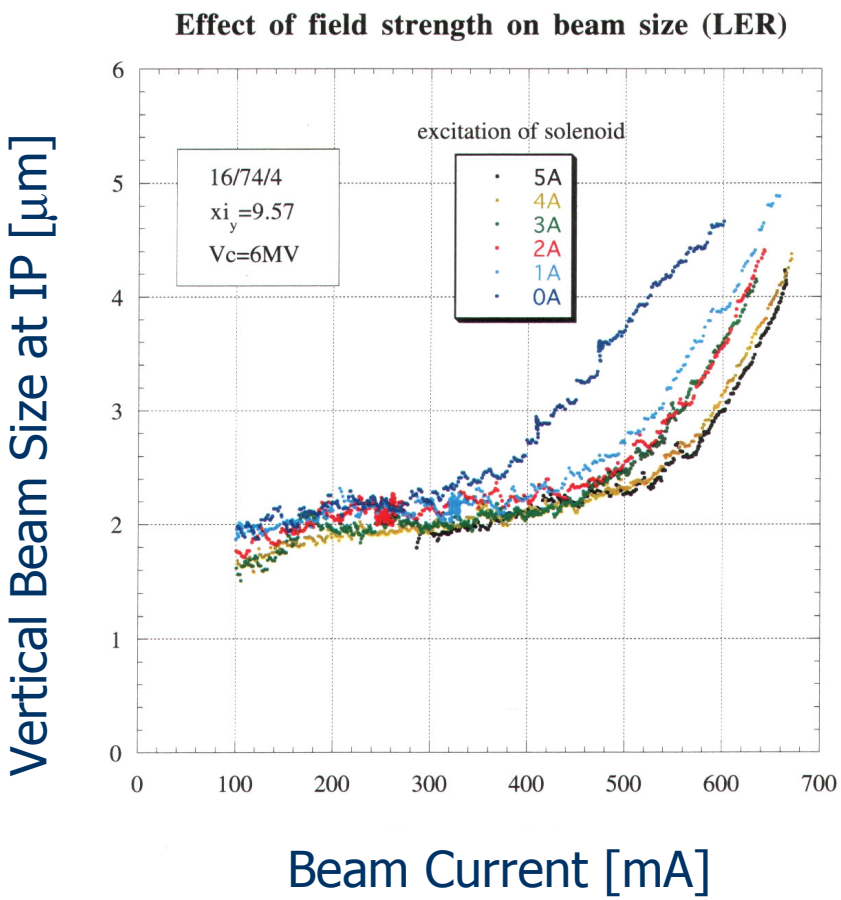




The behaviors are very similar to those of pressures.

# Relation to Beam Size Blow up

- Dependence on Solenoid




The change from 0A to 1A is biggest for both case.

# Summary

(1) The non-linear pressure behavior has been observed in the KEKB LER (positron ring).

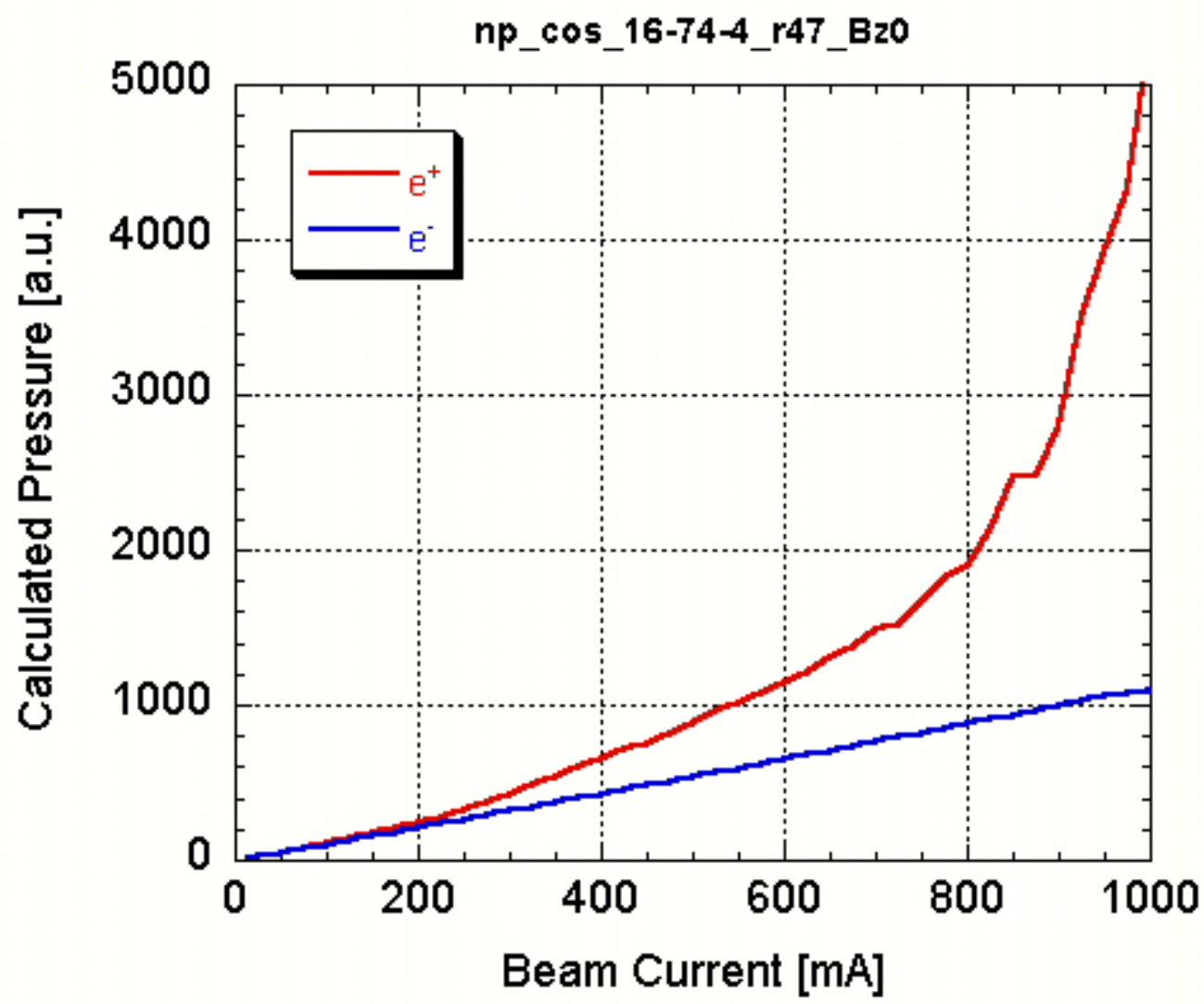
(2) A simple 2D simulation was performed assuming that the pressure behavior occurs by the electron multipactoring.

(3) The results reproduced the observed pressure dependence on the bunch fill pattern and the external magnetic field.

(4) The pressure behavior seems to have some relation to the blow up of the beam size.

(5) Further study is necessary to clarify the non-linear pressure rise in detail and to investigate the relation to the blow up of the positron beam size.

# e- and e+


np_cos_16-74-4_r47_Bz0
Calculated Pressure [a.u.]
Beam Current [mA]
e+
e-
0
1000
2000
3000
4000
5000
0
200
400
600
800
1000